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ORIGINAL PAPER

Evaluation of formaldehyde emission from particleboard using the large chamber and desiccator method at various loading ratios

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Abstract: We studied formaldehyde emission from uncoated particleboard with 16-mm thickness using the large chamber and the desiccator method. A chamber of 28.4 m^3 was installed to simulate a mobile home. The formaldehyde off-gassing properties of particleboard were evaluated using the chamber. The relationship between the concentration obtained by the chamber and the values by the desiccator test was discussed in this study under different conditions of conditioning day, air exchange, and loading ratio. These two methods were compared and discussed regarding the formaldehyde emission level. Three loading ratios, 0.429 m^2/m^3, 0.264 m^2/m^3, and 0.132 m^2/m^3, were chosen to represent different applications of particleboard products. There was strong correlation between emissions and air exchange rates at equal product-loading ratios in the large chamber, the related coefficient R^2 exceeded 0.90. There was also an indication of a generic correlation between the large chamber and the two-hour desiccator test with a single product designated loading ratio, air exchange rate, and climatic conditions.

Keywords: formaldehyde emission; particleboard; large chamber; desiccator

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Introduction

Large environmental chambers are used in the United States, Europe and Asia to simulate the atmosphere of homes containing formaldehyde-emitting wood products. The formaldehyde emission from wood-based panels is determined in the chamber with a defined temperature, humidity, loading ratio, and ventilation rate. However, every home has different amounts of particleboard and hardwood plywood wall paneling, as well as different ventilation characteristics. For example, mobile homes generally contain proportionally much more of these materials than do conventional homes. Standard test conditions can't be very correct evaluation of the actual situation.

On the other hand, the chamber method is a time-consuming method and it also requires special equipment, which is considered as an arbitration test method. A minimum chamber volume of 22 m^3 is allowed in American standard ASTM E1333-2002. In the European standard, ENV 717-1, three different chamber sizes, ≥12 m^3, 1 m^3, and 0.225 m^3, are specified. The test in ENV 717-1 takes 10–28 days, and at least two analyses of the chamber concentration are made daily during the test period to calculate the steady state concentration. The drawbacks of emission tests in large chambers are that they require long test durations and expensive equipment. It is desirable to be able to relate the results of these large chamber tests to a small-scale test that might be more convenient and less expensive. Versions of the desiccator test have been used by the wood products industries as the standard test for formaldehyde emission for approximately twenty years. In Japan, formaldehyde emission from wood-based boards is standardizes by Japan Industrial Standards (JIS A 1460-2001; JIS A1901-2003) and Japanese Agricultural Standards (JAS 233-2003). They are also applicable to formaldehyde treated wood for preservation. The chamber methods and desiccator test are prescribed in JIS and JAS for the management of the products in factories.

In our study, a chamber of 28.4 m^3 was installed to simulate a

mobile home. The formaldehyde off-gassing properties of particleboard were evaluated using the chamber. The relationship between the concentration obtained by the chamber and the values by the desiccator test was discussed in this study under different conditions of conditioning day, air exchange, and loading ratio. These two methods were compared and discussed regarding the formaldehyde emission level.

Materials and methods

Physical description of chamber method

A schematic description and photographs of the test chamber are shown in Fig. 1 and Fig. 2. The inside wall of the chamber was made of aluminum to avoid reaction with formaldehyde. The internal dimensions of the chamber were 2.23 m wide, 5.29 m deep and 2.41 m high. As mentioned earlier, the large chamber test is impractical for routine testing. In the development of this formaldehyde emission standard, it is envisioned that the chamber test would be used periodically, with the bulk of the testing performed by the desiccator test. The amount of data relating the two tests is limited due to the continual improvements being made in both test methods.

Board loading

Three ratios of board surface area to chamber volume were chosen for the proposed standard to represent the different applications of particleboard products. A loading ratio of 0.429 m^2/m^3 is representative of particleboard used as flooring, either underlayment or mobile home decking, throughout a house or mobile home. A ratio of 0.264 m^2/m^3 was chosen as an intermediate loading for a variety of particleboard products used less extensively than the 0.429 m^2/m^3 loading. A study by The University of Iowa (Myers 1984) indicates that 90% of conventional homes contain no more than 0.264 m^2/m^3 of particleboard of any type. The 0.132 m^2/m^3 loading is representative of the loading of particleboard used for cabinetry and shelving in a mobile home.

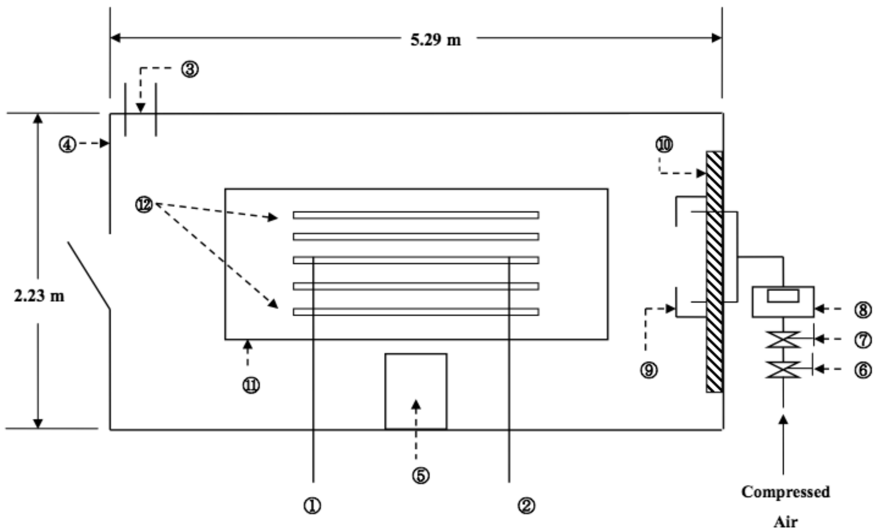

Fig. 1 Schematic description of the test chamber. 1 and 2: sample ports; 3: 3.8 cm exhaust hole with 6.35 I.D. copper tubing situated for sampling; 4: Walk-in cooler-aluminum; 5: Mini-remote split system air conditioner and atomizing humidifier; 6: Air regulator, adjustable; 7: Air regulator, 6.35 mm value orifice; 8: Diaphragm gas meter; 9: Air deflector-aluminum shaped gall wings for each fresh air inlet; 10: 1500-watt baseboard heater; 11: Slotted angle iron sample frame; 12: Sample.

Fig. 2 Photographs of 28.4 m^3 test chamber

Wood-based panels used in this study were uncoated particleboard with thickness of 16 mm, bonded with a high quality wholesome UF resin and produced from poplar particles. The properties of the UF resin and pressing specifications of particleboard produced by four companies were shown in Table 1. Ten particleboard panels each of mobile home decking under layment and industrial board were obtained from four different manufacturers. The thirty 1.2 m × 2.4 m full-sized panels were shipped in bundles, and the cover sheets were discarded upon sampling. For each chamber test the required number of panels was removed from the bundle, cut to size, and set out for 48 hours of conditioning. Meanwhile, the panel trim was prepared for analysis by the desiccator test (ASTM D 5582-2006).

Table1. Properties of UF resin and pressing condition

Item	Content
Molar ratio (F:U)	1.02–1.30
Viscosity 25°C, Pa·s	0.250–0.320
Solid content, %	65
pH	7.5–8.3
Content[a], %	Face: 10.2–11.3; Core: 7.4–8.0
Wax[a],%	0.3–0.5
Catalyst[b], %	Face: 0.32–0.75; Core: 2.0–3.0
Press temperature[c], °C	150–160

a: percent of dry furnish; b: percent of resin solution added to resin before spraying. The catalyst is ammoniumchloride (NH_4Cl); c: press time 10 $s{\cdot}mm^{-1}$.

An important factor in the desiccator test is the length of conditioning time allowed before testing. Emissions change over time (Meyer et al. 1980; Roffael 1975; Tohmura et al. 1998) and lengthening the conditioning time will improve the precision of the test. However, timely results are required of a quality control test. In this study, desiccator tests were performed using a variety of conditioning periods to obtain some indication of how these modifications affect the correlation with the large chamber test. In addition to the different conditioning times, some matched samples were tested with the specimen edges sealed in paraffin. This modification of the standard desiccator test is thought to compensate for the large edge area exposed in the desiccator and to make it more predictive of large panel behavior in the chamber test.

The proper air exchange rate is a difficult variable to identify. Some evidence indicate that an air exchange rate of 0.5 air changer per hour is similar to those found in mobile home, while 1.0 air change per hour is far more typical of conventional housing. There are also indications that the energy efficient “tightening” of houses with the resultant reduction in air exchange rate adds to the overall indoor air pollution problem and increase the indoor moisture condensation phenomenon.

Desiccator tests, using the standard 24-hour cut conditioning period, were performed on the panel trim from all panels cut to size and tested in the large chamber. In addition, desiccator tests were performed using different conditioning periods. The panels used in the 0.13 and 0.132 m^2/m^3 chamber tests were tested in the desiccator after 24, 48, and 168 h cut conditioning, in both the conventional manner and with the specimen edges sealed with paraffin. The panels tested in the large chamber at 0.264 m^2/m^3 were given one day and seven days of conditioning as panel segments with a minimum size of 0.36 m^2. One inch was trimmed from each panel edge and discarded. Some samples were tested immediately upon cutting, and some were tested after 24 hours of cut conditioning, in both the normal and edge sealed manner.

Chamber tests were performed at three loading ratios for each product. For the 0.429 m^2/m^3 loading, three panels 0.9 m × 2.4 m were used; for the 0.264 m^2/m^3 loading, two 1.2 m × 1.68 m panels were used, and for the 0.04 m^2/m^3 loading, one 1.2 m × 1.68 m panel was used. After 48 hours conditioning at 25°C, 50% relative humidity (RH), and an ambient background level of less than 0.1 ppm formaldehyde, the panels were placed on metal racks inside the chamber.

Operating conditions for the large chamber test were 25°C, 50% RH, and 1.0 air change per hour. After no less than 18 hours, two air samples were taken using a modification of the NIOSH P & CAM 125, chromatropic acid method, with samples collected in 1% sodium bisulfite solution (Meyer et al.1980). The following day a second pair of measurements wasmade and averaged with those of the preceding day. The air exchange rate was then lowered to 0.5 air change per hour, and after 24 hours another pair of simultaneous measurements was made.

Results and discussion

It has been suggested that formaldehyde emission as measured in the desiccator test may not be indicative of large panel emissions due to the high ratio of edge area to face area characteristic of these specimens (Que et al. 2007; Risholm-Sundmana et al. 2007). To determine if this is indeed the case, we compared the results of desiccator tests with edges sealed with paraffin and the results of the standard desiccator test with the large chamber test. Fig. 3 shows formaldehyde concentrations in the large chamber at 0.429 m^2/m^3 versus the standard two-hour desiccator value and the desiccator value with specimen edges sealed. Fig. 4 and Fig. 5 show the same information for chamber loading of 0.264 m^2/m^3 and 0.132 m^2/m^3. The correlation between edge-sealed desiccator values and the large chamber was slightly better than between the standard desiccator and the chamber, but the difference was not significant.

In Fig. 6, the edge-sealed two-hour desiccator values are plotted against the standard unsealed two-hour desiccator test values from matched specimens. All received the same treatment, including the same 24-hour cut conditioning. There is no indication that any of these products, mobile home decking, under layment, or industrial board, had a ratio of edge-to-surface emission appreciably different from the rest of the products. Strong correlation (R^2 = 0.992) was achieved when using the same treatment conditions.

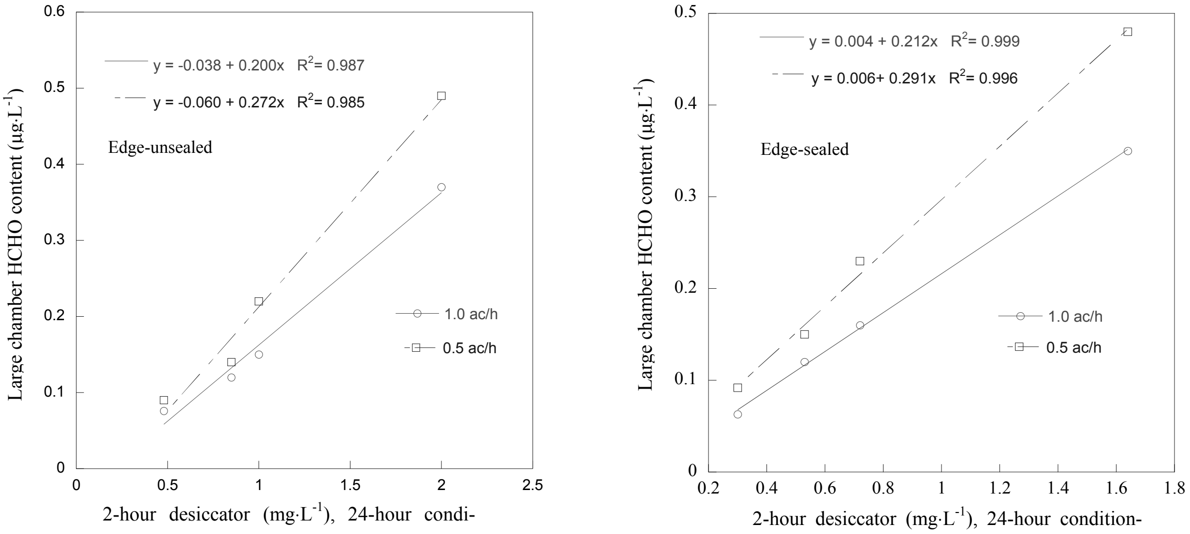

Fig. 3 Correlation of large chamber test at 0.429 m^2/m^3 to 2-hour desiccator test

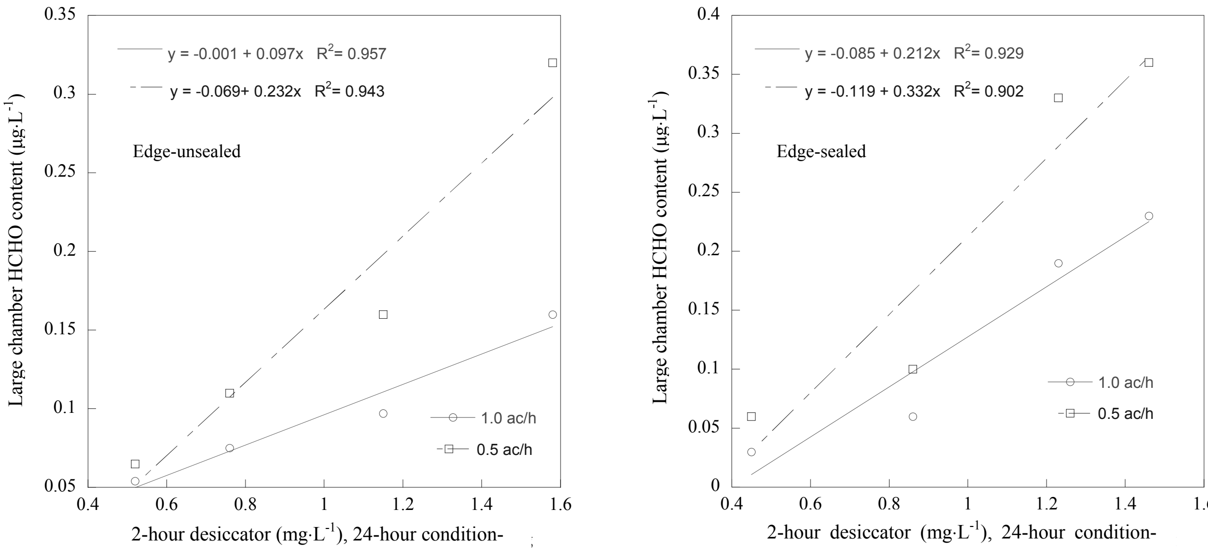

Fig. 4 Correlation of larege chamber test at 0.246 m^2/m^3 to 2-hour desiccator test

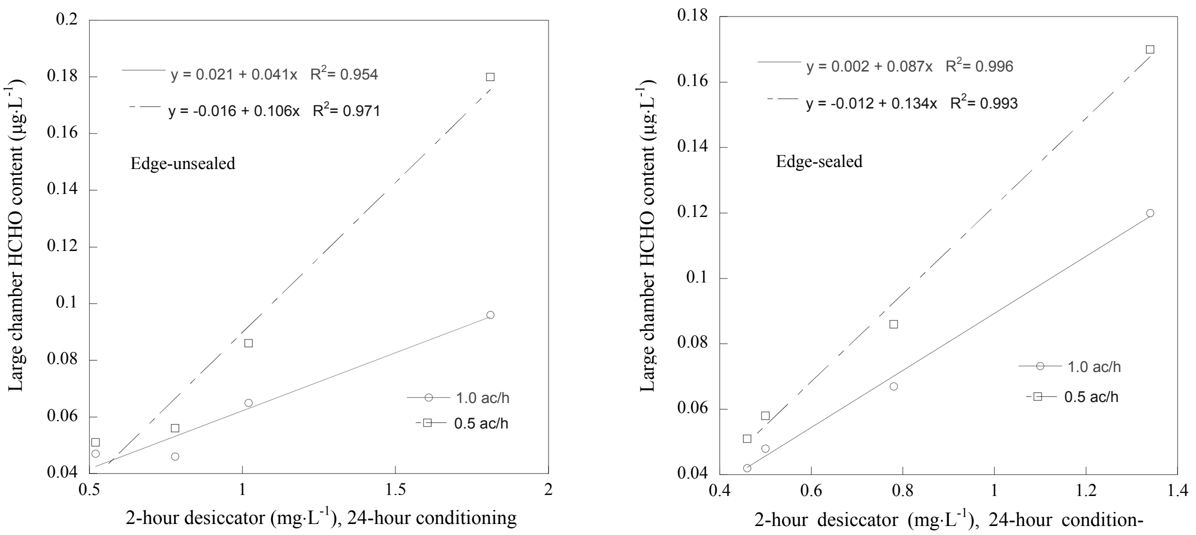

Fig. 5 Correlation of larege chamber test at 0.132 m^2/m^3 to 2-hour desiccator test

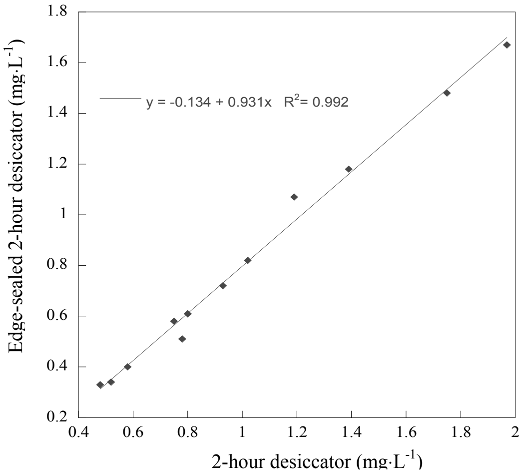

Fig. 6 Comparison of normal and edge-sealed 2-hour desiccator test

The panels were also tested with a variety of conditioning periods. Various conditioning times were tested because the optimum conditioning time may well depend upon the specific use of the test results. There are two conflicting philosophies concerning the test. One calls for the desiccator test to become more refined and more discriminating. The other views the test as a quality control tool, which balances precision with the ability to provide data in a timely manner. Although allowing seven days for the board to equilibrate before testing might give more consistent results, it is too long to be useful for quality control at a production facility.

Fig. 7 and Fig. 8 show the relationship between the large chamber test and desiccator tests with a seven-day cut conditioning period. It appears that the seven-day cut conditioning period is no better for the prediction of large chamber test results than the desiccator test with 24-hour conditioning. This could be because the desiccator tests performed after 24 hours are chronologically closer to the chamber test than those performed after seven days. It is possible that if panels were conditioned seven days prior to the chamber test, there might be a greater difference. Panels that had the expected decrease in formaldehyde emission had been stored for a longer period of time before testing than those panels that showed an increase.

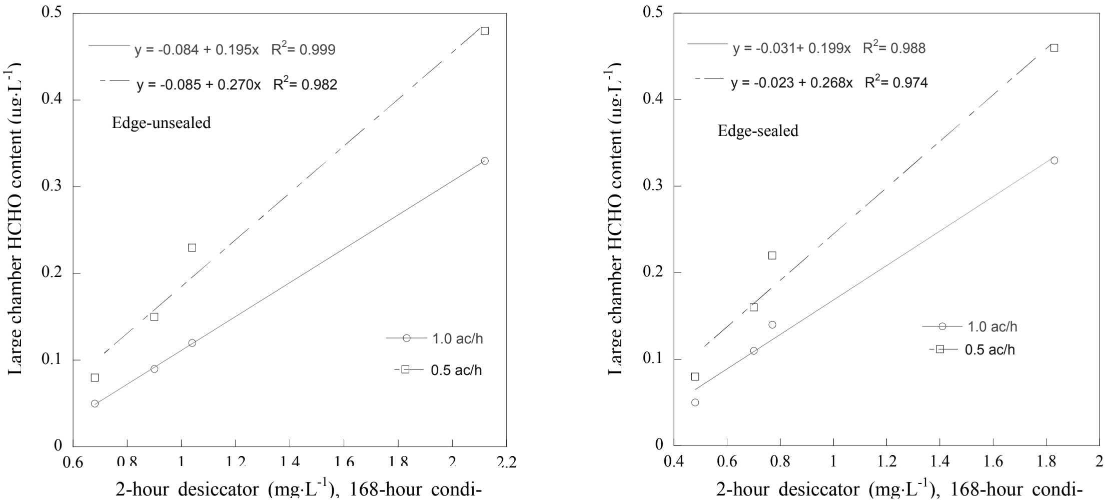

Fig. 7 Correlation of larege chamber test at 0.429 m^2/m^3 to 2-hour desiccator test

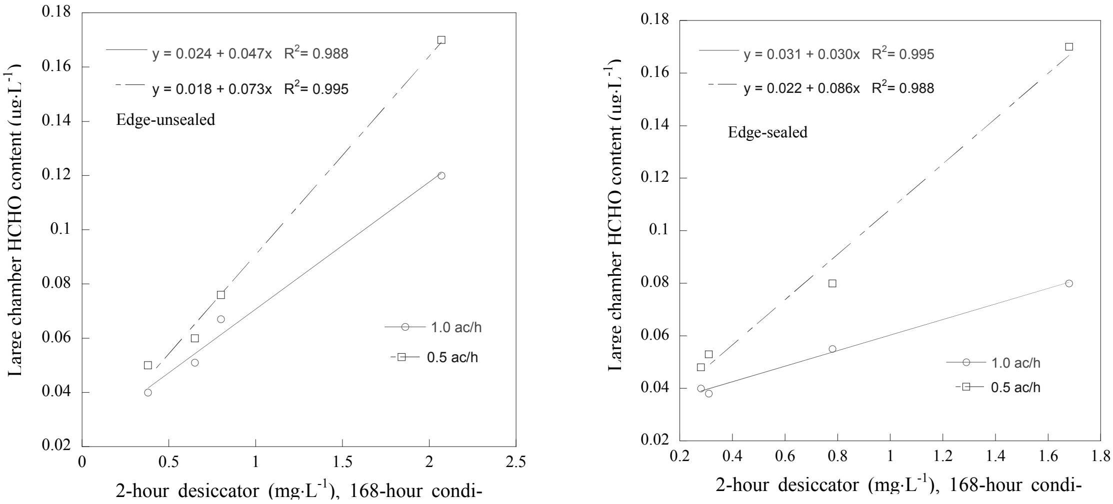

Fig. 8 Correlation of larege chamber test at 0.132 m^2/m^3 to 2-hour desiccator test

Conclusions

Product standards for formaldehyde emission from particleboard have been developed by many countries, the standards are based on the large chamber test and are compatible with those proposed or in effect in states that have addressed the subject. The two-hour desiccator test can be used very effectively to predict the results of large chamber tests. There is no significant improvement in the correlation as a result of increasing the desiccator test conditioning time to seven days from the standard 24 hours, or as a result of sealing specimen edges with paraffin. Formaldehyde concentrations in an environmental chamber can be mathematically modeled with concentration directly dependent upon the amount of board present and inversely proportional to the amount of ventilation. Under loading and air exchange conditions likely to be encountered in the home environment, the rate of emission is relatively constant for a given panel. The variation in emission rate is thought to be linear with respect to ambient formaldehyde concentration.

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